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Application of livestock manure and edamame harvest waste to improve the chemical properties of acid dry land

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Abstract

South Kalimantan has a large dry land. It is classified as acidic and has the potential for agricultural cultivation, especially food and horticulture crops. However, the problem with its use as agricultural land is the low level of soil fertility. This is evidenced in its low content of soil organic matter, acidic soil pH, low soil CEC, low soil exchange bases, high Al and Fe content. This study aims to improve soil chemical properties in acid dry land by the application of livestock manure and edamame harvest waste (EHW). It was compiled using a Nested Factorial Randomized Block Design, where the edamame harvest waste was nested in livestock manure. The treatment level of the first factor was chicken, cow, and goat manure, while the second was 0%, 25%, 50%, and 75% EHW. The results showed that the treatment of 100% chicken manure + 0% EHW increased soil pH by 9% compared to 25% chicken manure + 75% EHW. Furthermore, treatment of 100% goat manure + 0% EHW increased soil pH compared to 50% goat manure + 50% EHW and 25% goat manure + 75% EHW by 11.69% and 14.28%, respectively. The treatment of 100% chicken manure increased soil organic C by 38.16% compared to 25% chicken manure + 75% EHW. Meanwhile, the treatment of 100% goat manure increased soil organic C compared to 50% goat manure + 50% EHW and 25% goat manure + 75% EHW by 36.23% and 55.83%, respectively.

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Introduction

On a global scale, about 30% of the total land area is acid dry land spread in the tropics and sub-tropics (Takala, 2019). This land has the potential to be developed into agricultural land, but there are many obstacles in its development, such as being phytotoxic. This causes nutrient deficiency, unavailability of important nutrients such as calcium, magnesium, and phosphorus, as well as the toxicity of aluminum and iron (Ritchie, 1998; Hede *et al.*, 2001; Taye, 2007). The dominance of aluminum in ion-exchange complexes of acid soil directly affects growth, specially cultivated plants (Kochian *et al.*, 2004). Furthermore, the increase in soil acidity and Al^{3+} occur due to intensive agricultural cultivation systems and continuous use of acid-forming inorganic fertilizers (Deressa, 2013).

This condition causes a decrease in soil quality leading to loss of nutrients and a decrease in the availability of P, Ca, and Mg. Furthermore, it increases the solubility of toxic metals such as Al and Mn. These elements affect root growth and nutrients, water uptake and cause a decrease in microbial population and activity (Takala, 2019). It is accompanied by changes in soil pH since its productivity tends to decrease while the need for fertilizer continues to increase (Las *et al.*, 2006; Yuliar, 2006).

Generally, organic and chemical fertilizers are used with lime to overcome the low quality of the soil. Organic matter should be added to improve soil properties and aeration since it will be less prone to compaction compared to those with low organic matter. Furthermore, it is also useful in accelerating the activity of microorganisms, thereby increasing the speed of decomposition and accelerating the release of nutrients (Sutanto, 2004).

The organic matter used includes either pre-harvest, harvest, and post-harvest agricultural waste. Hakim and Mursidi (1984) stated that the role of organic matter in the soil is the key to the success of dryland farming. However, returning crop residues is not enough to maintain soil organic C content in the initial conditions of 2-2.5%. Therefore, it is necessary to add other organic matter in the form of livestock manure, such as chickens, cows, goats, and others.

The use of edamame harvest waste and livestock manure as organic matter is one alternative selected to improve soil properties as well as overcome scarcity and rising prices of commercial fertilizers in the market. Recently, the use of edamame harvest waste and livestock manure as soil organic matter is not optimally conducted.

The test results from the Soil Laboratory of Faculty of Agriculture, Lambung Mangkurat University in 2020 showed that the total N content in harvest waste in the form of edamame leaves was 2.27%, and in stalks and stems was 1.63%, with the C/N ratio of edamame harvest waste of 15.36%. Edamame harvest waste is also known to contain 0.34% P and 2.41% K. The production rate of edamame harvest waste is estimated to reach 3.3 tons ha^{-1}. Therefore, it should be optimally used in further agricultural cultivation activities.

Generally, livestock manure obtained from chickens, goats, and cows is directly used in agricultural cultivation activities, and it contains many important nutrients for plants. Chicken, cow and goat manure contains (1.5% N, 1.3% P_2O_5, 0.8% K_2O), (0.3% N, 0.2% P_2O_5, 0.15% K_2O) and (0.7% N, 0.4% P_2O_5, 0.25% K_2O) (Lingga and Marsono, 1991) respectively. The potential of livestock manure is also large where cows, goats, and chickens produce manure of 15-25 kg day^{-1}, 1-2 kg day^{-1}, and 0.05-0.15 kg day^{-1} (Setiawan, 2002).

The use of edamame harvest waste and livestock manure should overcome land fertility problems in supporting efforts to increase production in a zero-waste cultivation system. Furthermore, it has an economic value that is feasible to be applied since the production can be optimally increased, and the agricultural environmental ecosystem is easily maintained to increase farmers' income.

Materials and methods

This study was conducted from June to October 2020 at Gunung Kupang Trans Road, Banjarbaru City, South Kalimantan, and the Soil Laboratory of the Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, South Kalimantan. Furthermore, a randomized block design of nested classification was used. The first factor was the type of manure with three levels, namely chicken, cow, and goat manure. The percentage of edamame harvest waste (EHW) with four levels, namely 0%, 25%, 50%, and 75% EHW was the first factor. There were 12 treatment combinations repeated three times. Therefore 36 experimental units were obtained.

The dry land used was located on Gunung Kupang Trans Road, Banjarbaru City, South Kalimantan and was an acid mineral soil type (3°48'47" S and 114°86'34" E). Furthermore, the initial soil analysis was carried out to determine the characteristics before being given treatment. The nutrient contents of livestock manure (chicken, goat, cow) and edamame harvest waste were also analyzed. Meanwhile, the total manure used was 49.5 kg each, while the edamame harvest waste was 148.5 kg. The dose of organic matter was 10 tons ha^{-1} (Saputra and Sari, 2021) used as a reference in determining the treatment combinations.

Soil processing included clearing land, making beds, and lime application. The land was cleared of weeds using a machete, and the beds were processed using a hoe with a height of 20-25 cm, a bed size of 3 m ×3 m, and a distance between beds of 50 cm. After the beds were made, lime was applied two weeks before planting at a dose of 600 kg ha^{-1}.

The application was carried out by chopping the edamame harvest waste and then mixing it with livestock manure according to the treatment until evenly distributed. Furthermore, the mixture of these materials was sown into the beds, and the land was incubated for 14 days before sub-sampling was taken to test changes in soil properties. After incubation, the soil sub-samples were taken in each plot for laboratory analysis of changes in properties, including pH, exchangeable Al (Al-dd), organic C, CEC, NH_4^+, NO_3^-, available P, and exchange bases (K-dd, Na-dd, Ca-dd, Mg-dd).

Data were analyzed using GenStat 12th edition to determine the effect of livestock manure and edamame harvest waste on changes in some chemical properties of dry acid soil. Furthermore, they were tested for homogeneity before being analyzed for variance with the F test at 1% and 5% significance levels. When the analysis of variance results showed an effect on the treatment given, it is continued with the Duncan's Multiple Range Test at a 5% significance level (Duncan, 1995).

Results and discussion

Characteristics of research soil

The acid mineral soil used for study was Ultisols, and it had a clay texture, and the content of nitrogen, phosphorus, potassium, and organic C was very low (Table 1). This claim was consistent with the study of Prasetyo and Suriadikarta (2006) that stated the nutrient content of Ultisols is generally low due to intensive alkaline leaching. Meanwhile, the organic matter content is low due to the rapid decomposition process and partly carried away by erosion.

The reaction (pH) of the soil was acidic, while the cation exchange capacity was moderate. This was because Ultisols from South Kalimantan developed from sedimentary rocks of sandstone and claystone with a soil cation exchange capacity of 3–18 cmol (+) kg^{-1} and a pH of 3.70–5.00 (Prasetyo and Suharta 2000; Yatno *et al.* 2000; Prasetyo *et al.* 2001).

Chemical characteristics of livestock manure and edamame harvest waste

The pH of chicken and goat manure was alkaline, while that of cow manure was slightly alkaline. Furthermore, the nitrogen content of the three livestock manure types was very high. The organic C content of chicken and cow manure was very high, while that of the goat was high and the C/N ratio was low – very low (Table 2).

Table 1. Characteristics of dry acid soil used in the research.

No.	Parameter	Unit	Content
1.	Texture		
	Sand	%	36.86
	Dust	%	20.11
	Clay	%	38.44
	Very Fine Sand	%	2.59
2.	pH (H_2O)		5.49
3.	N-total	%	0.10
4.	Organic C	%	0.50
5.	CEC	cmol (+) kg^{-1}	18.05
6.	P_2O_5	ppm	4.72
7.	K_2O	mg $100g^{-1}$	7.34

The pH of the three livestock manure types fulfilled the requirements based on the Minister of Agriculture Regulation No. 70/2011 on the requirements and registration of organic and biological fertilizers. However, the nitrogen content of the three livestock manure types did not fulfill the requirements. The phosphorus content that fulfilled the requirements was only chicken and goat manure. Meanwhile, the potassium content that fulfilled the requirements was chicken manure.

Table 2. Chemical characteristics of livestock manure and edamame harvest waste.

No.	Parameter	Unit	Chicken manure	Cow Manure	Goat Manure	Edamame Harvest Waste	
						Leaf	Stem
1.	pH (H_2O)		8.68	8.46	8.96	-	-
2.	N-total	%	1.95	1.53	1.17	2.27	1.63
3.	Organic C	%	6.94	8.30	3.15	29.67	28.74
4.	C/N ratio		3.56	5.42	2.69	13.07	17.63
5.	P_2O_5	%	4.88	1.65	2.08	-	-
6.	K_2O	%	2.19	1.16	0.73	-	-

The edamame harvest waste fulfilled the requirements as green manure. This was because it has very high nitrogen and organic C content, and the C/N ratio was close to the soil C/N ratio (Table 2). The claim was consistent with Dahlianah's (2014) study, where it was stated that plants used as green manure should store more water and have a C/N ratio close to the soil C/N ratio (10-20). Edamame is a type of leguminous plant that contains quite high nitrogen and a low C/N ratio (Djojosuwito, 2000).

The harvest waste generated from edamame cultivation ranges from 25-30%, therefore it has the potential to be used as green manure. This was consistent with Dahlianah's (2014) study, where it was stated that the source of green manure can come from harvest residues or abundant production.

Improvement of soil chemical properties

The application of livestock manure and edamame harvest waste (EHW) improved soil pH (Fig. 1a). The treatment of 100% chicken manure + 0% EHW increased soil pH compared to 25% chicken manure + 75% EHW. Furthermore, the treatment of 100% goat manure + 0% EHW increased soil pH compared to 50% goat manure + 75% EHW and 25% goat manure. When the percentage of EHW given to the land increases, then the soil pH tends to decrease. This was due to the ongoing EHW decomposition process. The EHW given to the land was fresh without going through the composting process first. Therefore, the decomposition process occurs when the EHW is given to the land. Pasaribu *et al.* (2018) stated that an increase in soil pH would occur when the organic matter has been completely decomposed.

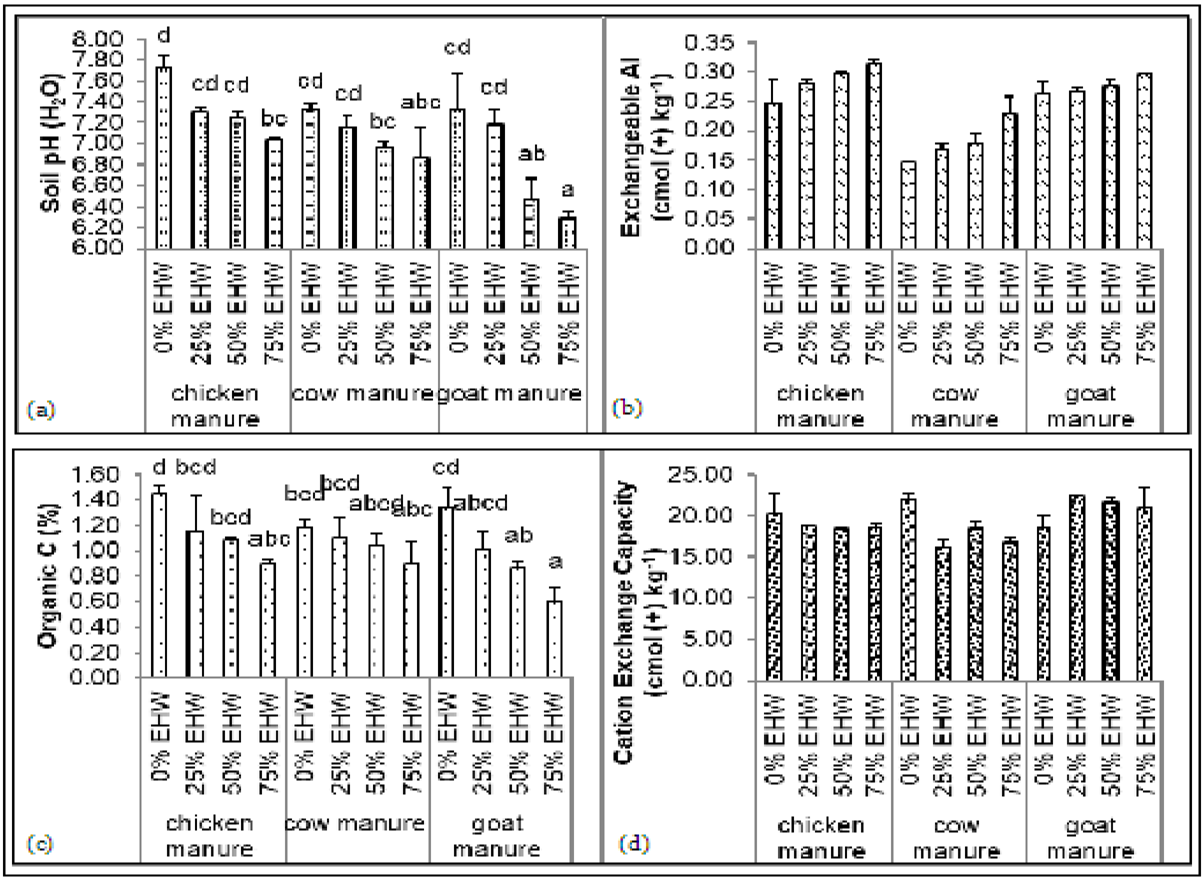

Fig. 1. Changes in (a) soil pH; (b) Exchangeable Al; (c) organic C; (d) Cation Exchange Capacity by the application of different manure and edamame harvest waste. The line above the bar chart is the standard error of the treatment (n=3). The same letter above the bar chart shows that the treatment has no different effect based on Duncan's Multiple Range Test (DMRT) at α of 5%.

The increase in soil pH occurred in the EHW treatment combined with chicken and goat manure. When the amount of manure given increases, the soil pH will increase. According to Ano and Ubochi (2007), the application of livestock manure (rabbits, pigs, goats, chickens, and cows) at doses of 10, 20, 30, and 40 tons ha^{-1} produced a consistent increase in soil pH. This was consistent with Saidy (2018), where it was that the magnitude of the increase in soil pH is determined by the type of organic matter, the amount of organic matter, and the amount of soil buffering capacity.

All treatments experienced an increase in soil pH (Fig. 1a) compared to the initial pH of only 5.49 (Table 1). The organic matter incubated in the decomposition process will release compounds in the form of acids or base cations, which will increase pH. This is in line with Hamed (2014), which states that the nutrient content provided from organic matter correlates with the length of the mineralization process required. Organic acids, as a result of decomposition, can bind H^+ ions as a cause of acidity in the soil since the pH increases. This is supported by Scnitzer (1991) which states that organic acids can bind H^+ ions through carboxyl groups which have a negative charge. Furthermore, Bayer *et al.* (2001) stated that the increase and decrease of soil pH is a function of H^+ and OH^- ions. When the concentration of H^+ ions increases, the pH will decrease, and when the concentration of OH^- ions increases, the pH will increase. Organic matter decomposed will produce OH^- ions which can neutralize the activity of H^+ ions.

Meanwhile, the acids will also bind Al^{3+} and Fe^{2+} to form complex compounds (chelates) since the ions are not hydrolyzed.

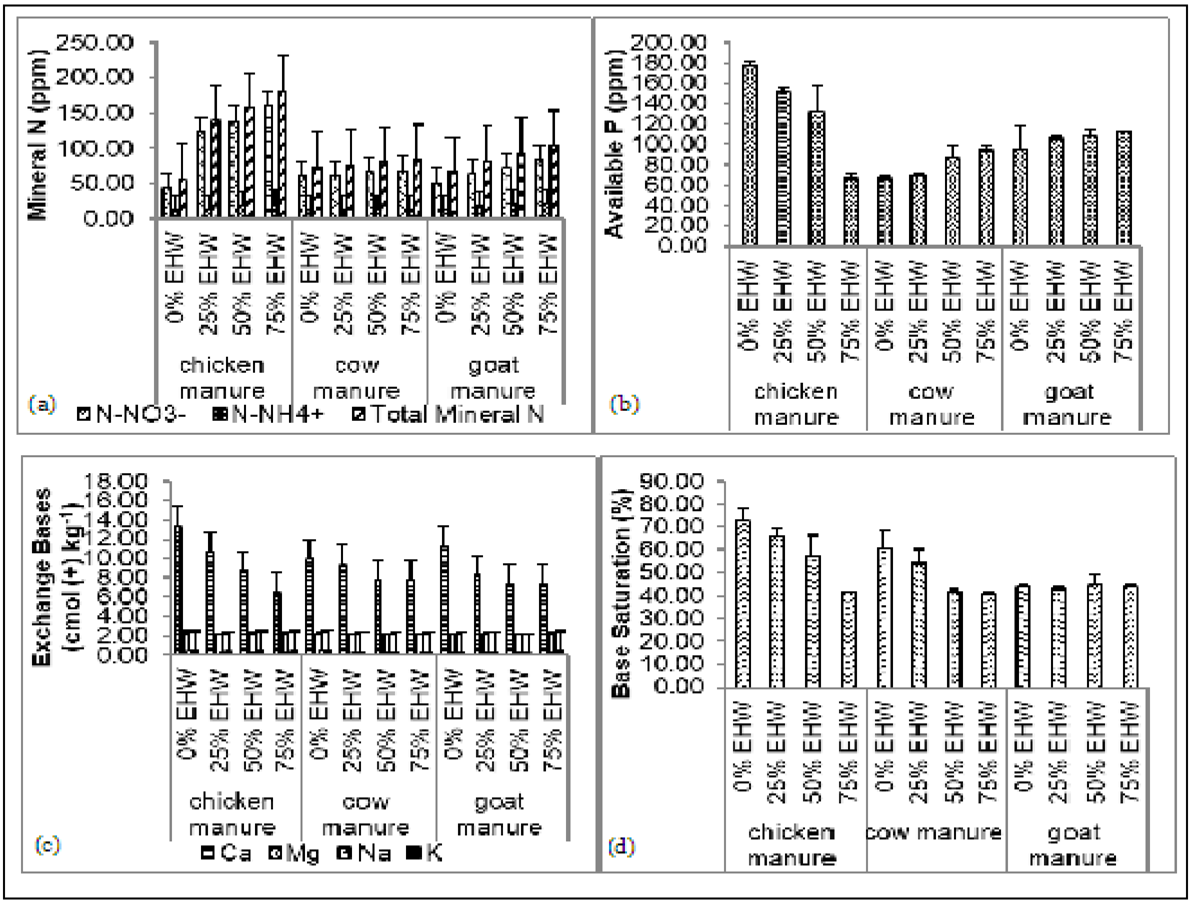

Fig. 2. Changes in (a) Mineral N; (b) Available P; (c) Exchange bases; (d) Base saturation with the application of different manure and edamame harvest waste. The line above the bar chart is the standard error of the treatment (n=3). The same letter above the bar chart shows that the treatment has no different effect based on Duncan's Multiple Range Test (DMRT) at α of 5%.

The application of livestock manure and EHW did not improve the exchangeable Al of soil (Fig. 1b). This was because the organic matter in the form of EHW given to the land was not completely decomposed. Tan (2010) stated that mature organic fertilizers could reduce the exchangeable Al. This is because organic fertilizers produce acids that will form chelate compounds with free Al since it decreases.

The data pattern formed due to the application of livestock manure and EHW tends to increase in exchangeable Al content along with the increase in the amount of EHW (Fig. 1b). This was inversely proportional to the soil pH due to the application of livestock manure and EHW. The data showed that the decrease in soil pH is accompanied by a decrease in the amount of EHW. Therefore, a decrease in soil pH increases Al-dd. However, the exchangeable Al in the soil is in very low due to the presence of lime. The lime given was 600 kg ha^{-1} since it reduces the exchangeable Al of the soil. Adiningsih and Prihatini (1986) stated that there is a very significant relationship between lime and Al levels with Al saturation. The process of liming is effective in reducing soil acidity (Wade *et al.*, 1986), and the application equivalent to 1 x exchangeable Al can reduce Al saturation from 87% to <20% (Adiningsih and Prihatini, 1986).

Another assumption that caused the low exchangeable Al content was the increase in soil organic C due to the application of livestock manure and EHW (Fig. 1c). Hakim *et al.* (1986) stated that organic matter given to the soil would react with metal cations to form synthetic compounds. Furthermore, metal cations such as Fe, Al, and Mn become insoluble, and their applications increase the formation of chelates which can suppress the solubility of aluminum in the soil solution.

The application of manure and edamame harvest waste (EHW) improved soil organic C (Fig. 1c). Meanwhile, the treatment of 100% chicken manure increased soil organic C compared to 25% chicken manure + 75% EHW. The treatment of 100% goat manure increased soil organic C compared to 50% goat manure + 50% EHW and 25% goat manure + 75% EHW. This was because chicken and goat manure is given to the land were decomposed and they increased organic C in the soil. Furthermore, the amount of chicken and goat manure given to the land was appropriate, and it caused an increase in soil organic C content. This was consistent with Bakayoko *et al.* (2009); Schulten and Leinwber (1991), which stated that the addition of manure to the soil can increase soil organic matter or slow down the depletion process. Ewulo *et al.* (2008) found that the provision of 10, 25, 40, and 50 kg ha^{-1} of chicken manure resulted in an increase in soil organic matter compared to the control treatment.

However, EHW with very high organic C (29.67%) cannot increase soil organic C due to incomplete decomposition and fast incubation time (14 days). This was confirmed by Prager *et al.* (2012) that reported the potential of *Sorghum bicolor, Crotalaria juncea*, and *Canavalia ensiformis* as green manure in the tropics. The study showed that soil treated with *Sorghum bicolor* associated with mycorrhizae increased the organic C content after being decomposed in the soil for 45 days. Therefore, the EHW given to acid dry land was completely decomposed since soil organic C with a higher EHW composition tends to be lower than those with a higher composition of animal manure. However, all treatments resulted in significantly higher soil organic C compared to the initial of only 0.55% (Table 1). Therefore, the application of livestock manure and EHW can increase soil organic C in acid dry land. The application of manure and edamame harvest waste (EHW) improved the cation exchange capacity (CEC) of the soil (Fig. 1d). The treatment of 75% goat manure + 25% EHW had the highest CEC value of 22.43 cmol (+) kg^{-1} (categorized as moderate), while the treatment of 75% cow manure + 25% EHW had the lowest of 16.27 cmol (+) kg^{-1} (categorized as low). However, several studies showed that the application of organic matter in the form of cow manure, straw, and Flemingia congesta could increase the organic matter content and cation exchange capacity (Nursyamsi *et al.*, 1997). Miller *et al.* (2016) found a linear and significant relationship between the application of manure and an increase in CEC value after 13 years. Meanwhile, no significant relationship was found when the observations were only one year. Therefore, the application of livestock manure and EHW to acid dry land is very good to be conducted sustainably to improve soil properties and support optimal plant growth and yields.

The cation exchange capacity of the soil in several treatments tended to have a higher value compared to the initial CEC of 18.05 cmol (+) kg^{-1} (Table 1). Harada and Akio (1975) stated that the value of cation exchange capacity (CEC) was influenced by clay minerals and soil organic matter, organic matter. Furthermore, the increase in the CEC value was influenced by the decomposition process of each organic matter which produces humic compounds to increase soil CEC. The increase in CEC was also caused by an increase in the negative charge of soil colloids. This negative charge comes from the carboxyl (COOH) and hydroxyl (OH) groups present in organic compounds. Furthermore, Stevenson (1994) stated that the presence of functional groups of organic compounds could produce several negative charges on soil colloids. This is consistent with Brady and Weil (2002), which states that the dissociation of COOH and OH groups from organic compounds can increase the negative charge in the soil, thereby increasing the CEC.

The application of livestock manure and edamame harvest waste (EHW) improved the availability of nitrogen in the soil, both N-NH_4^+, N-NO_3^-, and total mineral N (Fig. 2a). Furthermore, the application of chicken manure with a combination of EHW tends to have higher mineral N than cow and goat manure. This was consistent with Hou *et al.* (2012), which states that the application of chicken manure combined with inorganic fertilizers can significantly increase the N content of the soil. Busari *et al.* (2008) stated the increasing application of poultry manure from 5 to 10 tons ha^{-1} led to a significant increase in soil nitrogen. Fig. 2a showed that along with the increase in the composition of manure, the $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, and total mineral N also increased.

The application of livestock manure and EHW did not affect soil mineral N because the organic matter decomposition process was too short (14 days). Therefore, the nitrogen content in livestock manure and EHW cannot affect the availability of nitrogen in the soil. Hasibuan (2015) stated that the application of livestock and green manure from Gamal and Angsana leaves increased the availability of nitrogen in the soil after 6 weeks (42 days) of incubation. The testing results of the nutrient content in manure (Table 2) showed that the nitrogen content of the three manure types did not fulfill the requirements of the Ministry of Agriculture Regulation (2011). Therefore, it is suspected to be the cause of the lack of nitrogen availability in the soil.

The application of manure and EHW did not improve the availability of phosphorus in the soil. Similar to the availability of nitrogen minerals (Fig. 2a), the availability of phosphorus also has a similar graphic pattern (Fig. 2b). The application of chicken manure with a combination of EHW tends to have a higher available P than cow and goat manure. This is because chicken manure of 4.88% has the highest phosphorus content compared to other livestock manure (Table 2). Furthermore, it was proved that the decrease in the percentage of chicken manure application caused the chart pattern of available P to decrease.

Phosphorus is one of the essential nutrients derived from rocks and minerals contained in the soil. This nutrient causes acid mineral soil to have low phosphorus content (Table 1) because it comes from the low parent material. According to Firnia (2018), a common problem faced by phosphorus is that not all soil phosphorus can be available for plants. Buckley and Makortoff (2004) stated that manure is an important source of phosphorus nutrients. However, the excessive application causes problems in the availability of P and also by lowering the N:P ratio in manure compared to the ratio in plants. This is because plants will take up more N than P from manure since it should be applied in large quantities to supply the N needed by plants.

The application of livestock manure and EHW did not improve the availability of exchange bases in the soil, either Ca, Mg, Na, and K (Fig. 2c). This was due to the ongoing decomposition process of organic matter since the soil exchange bases do not have a significant change. Sevindrajuta (1996) stated that weathering results from enzymatic reactions liberate simple compounds such as Ca, Mg, and other nutrients. Furthermore, the decomposition process of organic matter in the soil will release nutrients such as N, P, K, Fe, Ca, Mg, and others into inorganic forms since they can be available for consumption by microorganisms and higher plants.

Miller *et al.* (2016) stated that the exchangeable Ca, Mg, and Na concentrations were lower in areas treated with poultry manure compared to control treatments. Furthermore, this study showed an increase in CEC with the application of cow manure. The possible estimation was that chicken manure has a higher C/N ratio than cow manure. A higher C/N ratio slows decomposition and lowers CEC. Furthermore, the decomposition of organic matter can increase the CEC due to the increase in negatively charged ions in the carboxyl and phenolic groups.

The application of manure and EHW did not improve base saturation in the soil. Fig. 2d showed that base saturation in chicken manure treatment tends to be higher than in others. Base saturation of all treatments was included in the moderate-very high category. Therefore, the application of livestock manure and EHW can improve the base saturation of acid dry land, but it is not statistically significant. Hardjowigeno (2010) stated that bases are easily washed since it causes low base saturation. The adsorption complex of soils with low base saturation is mostly filled with acidic cations, namely Al^{3+} and H^+. Too many acid cations, especially Al^{3+}, cause plants to be poisoned. This was consistent with Hardjowigeno (2010), where the adsorption complex is mostly filled with acidic cations, such as Al^{3+} and H^+ found in acid soils.

Conclusion

The application of livestock manure combined with edamame harvest waste in acid dry land improved some chemical properties of the soil. The treatment of 100% chicken manure + 0% EHW increased soil pH by 9% compared to 25% chicken manure + 75% EHW. Furthermore, the treatment of 100% goat manure + 0% EHW was also able to increase soil pH compared to 50% goat manure + 50% EHW and 25% goat manure + 75% EHW by 11.69% and 14.28%, respectively. Furthermore, the treatment of 100% chicken manure increased soil organic C by 38.16% compared to 25% chicken manure + 75% EHW. The treatment of 100% goat manure increased soil organic C compared to 50% goat manure + 50% EHW and 25% goat manure + 75% EHW by 36.23% and 55.83%, respectively.

References

Adiningsih SJ, Prihatini T. 1986. Pengaruh pengapuran dan inokulan terhadap produksi dan pembintilan tanaman kedelai pada tanah Podsolik di Sitiung II, Sumatera Barat. Prosiding Pertemuan Teknis Penelitian Tanah, Cipayung 10–13 November 1981. Pusat Penelitian Tanah, Bogor, p 139-150.

Ano AO, Ubochi CI. 2007. Neutralization of soil acidity by animal manure: Mechanism of reaction. African Journal of Biotechnology, p 364-368. https://doi.org/10.5897/AJB2007.000-2014.

Bakayoko S, Soro D, Nindjin C, Dao D, Tschannen A, Girardin O, Assa A. 2009. Effects of cattle and poultry manures on organic matter content and adsorption complex of a sandy soil under cassava cultivation (*Manihot esculenta* Crantz). African Journal of Environmental Science Technology **3,** p 190-197. http://dx.doi.org/10.5897/AJEST09.072

Bayer C, Martin-Neto LP, Mielniczuk J, Pillon CN, Sangoi L. 2001. Changes in Soil Organic Matter Fractions Under Subtropical No-Till Cropping Systems. Soil Science Society America Journal **65,** p 1473-1478. https://doi.org/10.2136/sssaj2001.6551473x

Brady NC, Weil RR. 2002. The Nature and Properties of Soils, 13th edition. Macmillan, New York.

Buckley K, Makortoff M. 2004. Phosphorus in Livestock Manures. In Advanced Silage Corn Management; Agriculture and Agri-Food Canada: Brandon, MB, Canada.

Busari MA, Salako FK, Adetunji MT. 2008. Soil chemical properties and maize yield after application of organic and inorganic amendments to an acidic soil in Southwestern Nigeria. Spanish Journal Agricultural Research **6,** p 691-699. https://doi.org/10.1071/SR16162

Dahlianah I. 2014. Pupuk Hijau Salah Satu Pupuk Organik Berbasis Ekologi dan Berkelajutan. Jurnal Klorofil **9(2),** p 54-56.

Deressa A. 2013. Evaluation of Soil Acidity in Agricultural Soils of Smallholder Farmers in South Western Ethiopia. Science, Technology and Arts Research Journal **2(2),** p 01-06. https://doi.org/10.4314/star.v2i2.98859

Djojosuwito S. 2000. Pertanian Organik dan Multiguna. Yogyakarta.

Duncan DB. 1995. Multiple range and multiple F tests. International Biometric Society Biometrics, p 1-42 http://dx.doi.org/10.2307/3001478.

Ewulo BS, Ojeniyi SO, Akanni DA. 2008. Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. African Journal Agriculture Research **3,** p 612-616.
https://doi.org/10.1016/j.jssas.2016.01.006

Firnia D. 2018. Dinamika Unsur Fosfor pada Tiap Horison Profil Tanah Masam. Jurnal Agroekotek, **10(1),** p 45-52.

Hakim N, Nyakpa MY, Lubis AM, Nugroho SG, Saul MR, Diha MA, Hong GB, Bailey HH. 1986. Dasar-Dasar Ilmu Tanah. Universitas Lampung, Bandar Lampung.

Harada Y, Akio I. 1975. Cation-Exchange Properties of Soil Organic Matter. Soil Science and Plant Nutrition **21(4),** p 361-369,
http://dx.doi.org/10.1080/00380768.1975.10432651.

Hasibuan ASZ. 2015. Pemanfaatan Bahan Organik dalam Perbaikan Beberapa Sifat Tanah Pasir Pantai Selatan Kulon Progo. Planta Tropika Journal of Agro Science **3(1),** p 31-40.
https://doi.org/10.18196/pt.2015.037.31-40.

Hede AR, Skovmand B, Cesati JL. 2001. Acid Soils and Aluminum Toxicity. In: Reynolds, M.P., Ortiz-Monasterio, J.I and McNab, A (eds.). Application of Physiology in Wheat Breeding, Mexico, D.F.: CIMMYT.

Hakim LHS, Mursidi. 1984. Usaha Peningkatan Bahan organik melalui pengelolaan pola tanam tanaman pangan dan pupuk hijau. Prosiding Pertemuan Teknis, Pusat Penelitian Tanah, Bogor.

Hamed MH, Desoky MA, Ghallab AM, Faragallah MA. 2014. Effect of Incubation Periods and Some Organic Materials on Phosphorus Forms In Calcareous Soils. International Journal of Technology Enhancements and Emerging Engineering Research, **2(6),** p 2347-4289.
https://doi.org/10.31186/terra.4.1.29-33

Hou X, Wang X, Li R, Jia Z, Liang L, Wang J, Nie J, Chen X, Wang Z. 2012. Effect of different manure application rates on soil properties, nutrient use, and crop yield during dryland maize farming. Soil Research Journal **50,** p 507-514.
https://doi.org/10.1071/SR11339

Kochian LV, Hoekenga OA, Pineros MA. 2004. How do crop plants tolerate acid soils mechanisms of aluminum tolerance and phosphorous efficiency?. Annual Review of Plant Biology **55,** p 459-493.
https://doi.org/10.1146/annurev.arplant.55.031903.141655

Las I, Subagyono K, Setiyanto AP. 2006. Isu dan Pengelolaan Lingkungan dalam Revitalisasi Pertanian. Jurnal Penelitian dan Pengembangan Pertanian **25(3),** p 174-192.
https://dx.doi.org/10.25105/me.v28i2.7169

Lingga, Marsono. 2004. Petunjuk Penggunaan Pupuk. Redaksi Agromedia. Jakarta.

Miller J, Beasley B, Drury C, Larney F, Hao X. 2016. Influence of long-term application of composted or stockpiled feedlot manure with straw or wood chips on soil cation exchange capacity. Compost Science and Utilization **24,** p 54-60.
https://doi.org/10.1080/1065657X.2015.1055009

Nursyamsi D, Adiningsih JS, Sholeh, Adimihardja A. 1997. Penggunaan bahan organik untuk meningkatkan efisiensi pupuk N pada Ultisol Sitiung, Sumatera Barat. Prosiding Kongres Nasional VI HITI. Jakarta, 12–15 Desember **1995,** p 319-330.

Pasaribu NR, Fauzi, Asmarlaili SH. 2018. Aplikasi Beberapa Bahan Organik dan Lamanya Inkubasi Dalam Meningkatkan P-Tersedia Tanah Ultisol. ANR Conference Series 1, p 110-117.

Peraturan Menteri Pertanian No.70/Permentan/SR.140/10/2011. 2011. Pupuk Organik, Pupuk Hayati dan Pembenah Tanah.

Prasetyo BH, Suharta N. 2000. Tanah-tanah pada landform utama di Propinsi Kalimantan Selatan. Potensi dan Kendalanya untuk Pengembangan Pertanian. Prosiding Seminar Nasional Reorientasi Pendayagunaan Sumberdaya Tanah, lklim, dan Pupuk. Cipayung, 31 Oktober–2 November 2000. Pusat Penelitian Tanah dan Agroklimat, Bogor, p 419-428.

Prasetyo BH, Suharta N, Subagyo N, Hikmatullah. 2001. Chemical and mineralogical properties of Ultisols of Sasamba Area, East Kalimantan. Indonesian Journal of Agricultural Science **2(2),** p 37-47. https://doi.org/10.21082/ijas.v2n2.2001.37-47

Prager M, Sanclemente O, Sánchez de PM, Gallego J, Ángel D. 2012. Abonos verdes: Tecnología para el manejo agroecológico de los cultivos. Agroecología **7,** p 53-62. https://doi.org/10.21474/IJAR01/11547

Ritchie GSP. 1989. The chemical behavior of aluminum, hydrogen and manganese in acid soils. 1-60. In Robson, A.D., ed., Soil Acidity and Plant Growth. Sydney: Academic Press.

Ritung S, Suryani E, Subardja E, Sukarman, Kusumo N, Suparto, Hikmatullah A, Mulyani C, Tafakresnanto Y, Sulaeman RE, Subandiono, Wahyunto, Ponidi N, Prasodjo U, Suryana H, Hidayat A, Priyono, Supriatna W. 2015. Sumber Daya Lahan Pertanian Indonesia: Luas, Penyebaran, dan Potensi Ketersediaan. IAARD Press. Jakarta.

Saidy AR. 2018. Bahan Organik Tanah: Klasifikasi, Fungsi, dan Metode Studi. Lambung Mangkurat University Press. Banjarmasin.

Saputra RA, Sari NN. 2021. Ameliorant engineering to elevate soil pH, growth, and productivity of paddy on peat and tidal land. IOP Conference Series: Earth and Environmental Science, **648(012183),** p 1-8. https://doi.org/10.1088/1755-1315/648/1/012183.

Schulten HR, Leinweber P. 1991. Influence of long-term fertilization with farmyard manure on soil organic matter: Characteristics of particle-size fractions. Biology and Fertility of Soils **12,** p 81-88.

Scnitzer M. 1991. Soil Organic Matter. The Next 75 Year Soil Science.

Setiawan AI. 2002. Memanfaatkan Kotoran Ternak. Cetakan ke tiga Penebar Swadaya. Jakarta.

Sevindrajuta. 1996. Peranan cacing tanah (*Pontoscolex corethrurur*) dan macam bahan organik dalam perbaikan beberapa sifat fisika Ultisol Rimbo Data dan hasil kedelai. Tesis. Program Pascasarjana Universitas Andalas. Padang.

Stevenson FJ. 1994. Humus chemistry; Genesis, composition, reactions. 2th. Editi-on. John Wiley and Sons, tnc. New york.

Sutanto R. 2004. Penerapan Pertanian Organik. Permasyarakatan dan Pengembangannya. Penerbit Kanisius. Yogyakarta.

Takala B. 2019. Soil Acidity and Its Management Options in Western Ethiopia: Review. Journal of Environment and Earth Science, **9(10),** p 27-35. https://doi.org10.7176/JEES/9-10-04

Taye B. 2007. An overview of acid soils their management in Ethiopia paper presented in the third International Workshop on water management (Wterman) project, September, 19-21, 2007, Haromaya, Ethiopia.

Wade MK, Aljabri M, Sudjadi M. 1986. The effect of liming of soybean yield and soil acidity parameters of three red yellow podzolic soils of West Sumatera.

Pemberitaan Penelitian Tanah dan Pupuk **6,** p 1-8.

Yatno E, Hikmat M, Suharta N, Prasetyo BH. 2000. Plinthudults di Kalimantan Selatan. Sifat morfologi, fisika, mineralogi dan kimianya. Prosiding Seminar Nasional Reorientasi Pendayagunaan Sumberdaya Tanah, lklim, dan Pupuk. Cipayung, 31 Oktober–2 November 2000, p 353–368.

Prasetyo, Suriadikarta. 2006. Karakteristik, Potensi, dan Teknologi Pengelolaan Tanah Ultisol untuk Pengembangan Pertanian Lahan Kering di Indonesia. Jurnal Litbang Pertanian. **25(2),** p 39-47. https://doi.org/10.25077/jsolum.17.2.21-28.2020

Yuliar. 2006. Program Penelitian Nutrisi Hayati untuk Keseimbangan Ekosistem. Peneliti Utama Bidang Mikrobiologi, Pusat Penelitian Biologi-Lembaga Ilmu Pengetahuan Indonesia (LIPI). Bogor.